$$\delta_\mu = \frac{11}{40}\phi_y l^2 + \left(\phi_\mu - \phi_y\right) l_p \left(l - \frac{l_p}{2}\right) \tag{4.12}$$

Or the ultimate displacement ductility capacity can be estimated by

$$\mu = 1 + 3.64\left(\frac{\phi_u}{\phi_y} - 1\right)\frac{l_p}{l}\left(1 - 0.5\frac{l_p}{l}\right) \tag{4.13}$$

For the retaining wall model (Figure 4.5) the ultimate displacement capacity at the top of the stem wall relative to its base can be estimated by

$$\delta_\mu = \frac{1}{5}\phi_y l^2 + \left(\phi_\mu - \phi_y\right) l_p \left(l - \frac{l_p}{2}\right) \tag{4.14}$$

Or the ultimate displacement ductility capacity can be estimated by

$$\mu = 1 + 5\left(\frac{\phi_u}{\phi_y} - 1\right)\frac{l_p}{l}\left(1 - 0.5\frac{l_p}{l}\right) \tag{4.15}$$

Most structures will not conform strictly to these ideal concentrated and distributed mass models. The model best representing the actual inertial force condition, however, should provide a reasonable estimate of displacement capacity and displacement ductility capacity. As a refinement, the structure can be investigated using the concentrated mass model with the distance from the base to the center of mass equal to the effective height.[1] The effective height l_{eff} representing the center of seismic force is

$$l_{eff} = \frac{\sum\left(m_n \phi_n l_n\right)}{\sum m_n \phi_n} \tag{4.16}$$

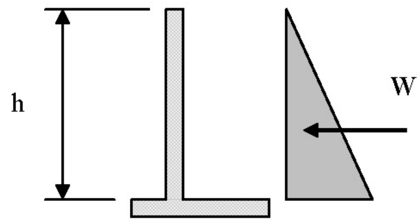
where

m_n = mass at level n of a multiple lumped mass system

ϕ_n = modal value at mass level n

l_n = height from base to mass at level n

[1] M.J.N. Priestley, 1995, "Criteria Review for Corps — Seismic Evaluation of Intake Towers," presented in Appendix G of this report.



$$\delta_y = \frac{Wh^3}{15EI} \qquad \phi_y = \frac{M}{EI}$$

$$M = \frac{Wh}{3} \qquad \delta_y = \frac{\phi_y h^2}{5}$$

Figure F.6 Yield displacement formulation

$l_p = 0.30 f_y d_b = 0.30(23.1)1.00 = 7.0$ in. (see Equation 4.7).

where

f_y = yield strength of the reinforcing steel (ksi) ← Use 23.1 ksi

d_b = diameter of reinforcing steel ← Use 1.0 in. for the square bars

δ_μ = 0.64 + (0.000242 – 0.000065) (7.0) (222 –3.5) = 0.64 + 0.27 = 0.91 in.

F.4.2 For a strong bond condition

With strong bond (full splice development) the ultimate displacement capacity will increase due to a larger yield displacement capacity and a longer plastic hinge length.

The cracking moment capacity M_{CR} per Equation 3.2 is

M_{CR} = 12 (18)^2 (410) ÷ 6 = 265,680 in.-lb = 22.14 ft-kips

The nominal moment capacity M_N is 76.18 ft-kips.

Since M_N is greater than 2M_{CR}, then the plastic hinge length l_p per Equation 4.8 is

l_p = 0.08 L + 0.15 (f_y) d_b = 0.08 (18.5 x 12) + 0.15 (33) (1) = 22.71 in.

Referring to Figure F.7, the ultimate displacement capacity is

$$\delta_\mu = \frac{\phi_y h^2}{5} + \left(\phi_\mu - \phi_y\right) l_p \left(l - \frac{l_p}{2}\right)$$

δ_μ = 0.91 + (0.004032 – 0.000092) (22.71) (222 – 11.35)
= 0.91 + 18.85 = 19.76 in.

This would indicate that with adequate splice length the displacement capacity would be much greater than the displacement demand, and displacement-based performance objectives would be met.